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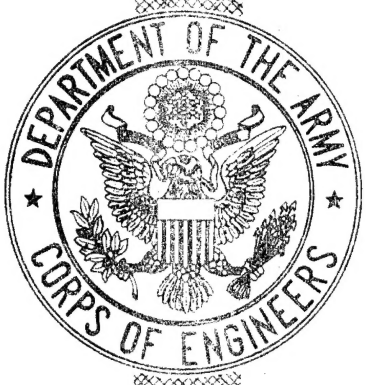


# CERL

Final Draft

# Guide for Pressure Grouting Cracked Concrete And Masonry Structures With Epoxy Resins



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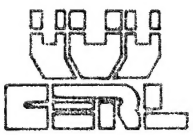

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# A GUIDE FOR PRESSURE GROUTING CRACKED CONCRETE AND MASONRY STRUCTURES WITH EPOXY RESINS

## SECTION I
## INTRODUCTION

### 1. Purpose and Objectives

This manual serves as a guide for purchase, performance, and use of materials by personnel engaged in the maintenance and repair of cracks in concrete and masonry structures, and to aid in:

a. Proper selection and employment of appropriate materials, equipment, and practices.

b. Competent inspection and evaluation of the work done.

c. Use of proper safety precautions.

The text of this guide covers both technical discussion and application procedures in order to aide the engineer in making decisions whether or not to pressure grout and, if so, by what method. Appendix C serves as a detailed grouting procedure guide for the individuals actually performing the work.

### 2. General Application

The guidance in this manual comprises descriptions and discussions of materials, equipment, and methods used in the maintenance and repair of cracked concrete and masonry. It applies to above and below ground housing, warehouses, technical buildings, special buildings, roads, runways, and any other concrete or masonry structure *except those, or the portions of those, which are under water or other fluid.*

Additional information useful to individuals concerned with concrete and masonry is contained in the technical manuals of the TM-5-600 series.

### 3. Inspection

Technical manual TM-5-615 states: "The production or repair of concrete and masonry work in such a fashion as to yield structures that will provide service for the anticipated period of use depends on the selection and employment of appropriate materials and practices. Satisfactory structures frequently are not obtained even though the materials provided and the practices selected are such as should yield satisfactory results. The reason for failure to achieve the desired results is usually attributable to inadequate supervision or inspection...". These words as well as the discussion in Article 3, Section 1, has equal, if not greater importance when applied to using epoxy resin compounds for pressure grouting cracked concrete

or masonry. Epoxy pressure grouting is often used in place of the alternate method of repair - complete structural replacement. The nature of the grouting technique conceals the work and thus it is possible to completely fail in the pressure grouting effort without any easy means of determining this failure. Proper inspection could prevent this and should include:

a. Identification, examination, and acceptance of the materials.

b. Control of proportioning and blending of materials.

c. Performance of tests on samples.

d. Continual inspection of the flow of grouting materials.

e. Preparation of records and reports.

4. Reasons for Pressure Grouting Cracks

There are several reasons why cracks occur in concrete and masonry structures. Among these are shrinkage, support settlement, overload, poor design, and earthquake. Whatever the cause, there may be very important reasons to repair the cracks by injecting an epoxy resin compound into the crack. Some of these reasons are:

a. To block the access of moisture and other foreign materials to the interior of concrete where freeze-thaw conditions occur.

b. To prevent water from corroding reinforcing and prestressing steel.

c. To waterproof a structure.

d. To restore the aesthetics to architectural concrete.

e. To restore structural integrity of a structure.

Whatever the reason for the repair, proper selection of materials and techniques along with good inspection can assure successful completion of a job.

## SECTION II
## SELECTION OF CRACKS TO BE PRESSURE GROUTED

### 5. General

Almost all cracks which occur in concrete and masonry can be injected with an epoxy resin compound. Certain exceptions do exist, however. *Whether or not it is desireable to pressure grout a crack remains a question of good engineering judgement.* Certain guidelines for making a decision are presented in this section.

### 6. Cracks to be Grouted

This guide does not attempt to cover grouting procedures for all crack sizes and all field conditions which may be encountered. However, the majority of the cracks encountered will meet the requirements herein set forth.

In general, under this guide, dry cracks above or below ground ranging from 0.003 inch to 0.050 inch in width* can be grouted successfully as long as they are accessible from one surface, and cracks ranging from 0.050 inch to 0.250 inch can be grouted if accessibility can be had to all fractured surfaces in order that the crack surfaces can be sealed.

If the surfaces of the cracks ranging from 0.05 inch to 0.250 inch in width cannot be completely sealed, the epoxy resin grouting compound herein specified is apt to flow out of the crack. Cracks in this category as well as cracks wider than 0.250 inch can be grouted using a mineral filled, thixotropic epoxy compound. Under such conditions, experts in the epoxy pressure grouting field should be called upon for advice.

Cracks on surfaces exposed to rainfall should not be grouted until all concrete has had an adequate opportunity to dry. In damp regions it may take 48 hours or longer after rainfall for a crack to dry. Therefore, if grouting is planned and rainfall is likely to occur, it is advisable to protect the crack from moisture. This can be done by placing a plastic sheet over the crack. Following rainfall it is difficult to determine when a crack has sufficiently dried to allow pressure grouting. A rule of thumb is to allow twelve hours longer for the crack to dry than for the exposed surrounding concrete surfaces. However, good engineering judgement should be used.

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* Crack widths can be measured with optical micrometers. Such a micrometer (Micro Mike 20S) can be obtained from DuMaurier Company, Elmira, New York. Feeler gauges can also be used for measuring crack widths.

7. Cracks Less than 0.003 Inch Wide

Cracks widths less than 0.003 inch in width should not be attempted. Research has shown that it is difficult to assure satisfactory results for such small cracks. It should be noted, however, that this restriction applies only to the exposed crack through which the epoxy must be initially injected. Once the epoxy has obtained access to the interior of the concrete or masonry, cracks down to 0.001 inch and even smaller have been successfully filled with epoxy.

An expert in pressure grouting with epoxy resins should be retained to handle cracks with surface openings less than 0.003 inch. With special techniques and under certain conditions cracks down to 0.001 inch can be successfully grouted.

8. Expansion Joints and Controlled Cracks

Prepared expansion joints designed as a necessary part of a structure should not be pressure groted with an epoxy resin compound under the scope of this manual. The same is true for designated controlled cracks. *The work herein described is not intended to cover 'working' or 'expansion' cracks and joints.*

9. Cracks Which are Wet or Underwater

Bonding an epoxy resin compound to a damp concrete surface requires special consideration. Special epoxy compounds are required for this work (many epoxy compounds will disperse in water). An expert in the area of repair and maintenance of concrete structures *with epoxy compounds* should be consulted before attempting any pressure grouting of cracks which are underwater or are wet.

10. Cracks Filled with Debris

Occassionally cracks are encountered in which the surface and possibly the interior of the crack is filled with debris or other foreign matter. If access can be obtained to inject epoxy into the crack, pressure grouting is feasible.

All cracks containing debris should be blown out with an air jet free of oil and moisture. A standard air jet nozzle under a 100 psi source is generally sufficient to clear the crack of debris. Generally, debris should not be considered as cause not to pressure grout a crack unless it is impossible to gain access to the interior.

Other than cleaning the surface as described above, no effort is warranted to attempt to clean the interior of a crack.

## SECTION III
## PRESSURE GROUTING EQUIPMENT

### 11. General

There are three general techniques used for injecting epoxy resin compounds into cracks. Two of the methods are general enough that they can be presented for use by the layman. The third method requires special equipment not readily available nor easily made. This method requires special two component nozzle mixing equipment and, therefore, is not recommended as a procedure to be used under this guide. The method, however, is an acceptable method and is herein included for description.

The first of the methods described below, the caulking hand gun, is recommended for use on all cracks over 0.020 inch wide and less than 18 inches in depth. It is also recommended for smaller width cracks ranging from 0.005 inch to 0.020 inch and less than 12 inches in depth when the job is limited to a maximum of 30 lineal feet of crack. This latter restriction is made because of the time differential which exists when grouting with a hand gun versus a pressure pot, the second method to be described.

The pressure pot method can be used to pressure grout all cracks covered within the scope of this guide, including those mentioned above, and is especially efficient for use on narrow cracks (0.003 in. to 0.005 in.) and cracks of depths greater than those mentioned above.

This section discusses only the pressure grouting equipment used for each technique. Crack preparation is discussed in a later section.

### 12. Caulking Hand Gun

There are several types of caulking guns and caulking gun cartridges which have been used for pressure grouting. This guide describes only one type because less difficulties are encountered and it is considered safer to use than other dissimilar types. The description herein given is not intended as an endorsement of any one product. On the contrary, it is offered for guidance in the selection of suitable equipment.

Figure 1 shows a hand operated caulking gun set up for use to inject epoxy. The components are shown in Figure 2. The caulking gun* consists of an 8 fluid ounce (1 pint) plastic cartridge (a), a plastic nozzle** (b) which threads into the cartridge, a plastic cap (c), a steel retainer barrel (d), and the ratchet handle and ram mechanism (e).

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* Equipment similar to that which is described is available from Semco, Products Research & Chemical Corporation, 18881 South Hoover Street, Los Angeles, California.

** A 4 inch nozzle with a 1/16 inch opening is recommended.

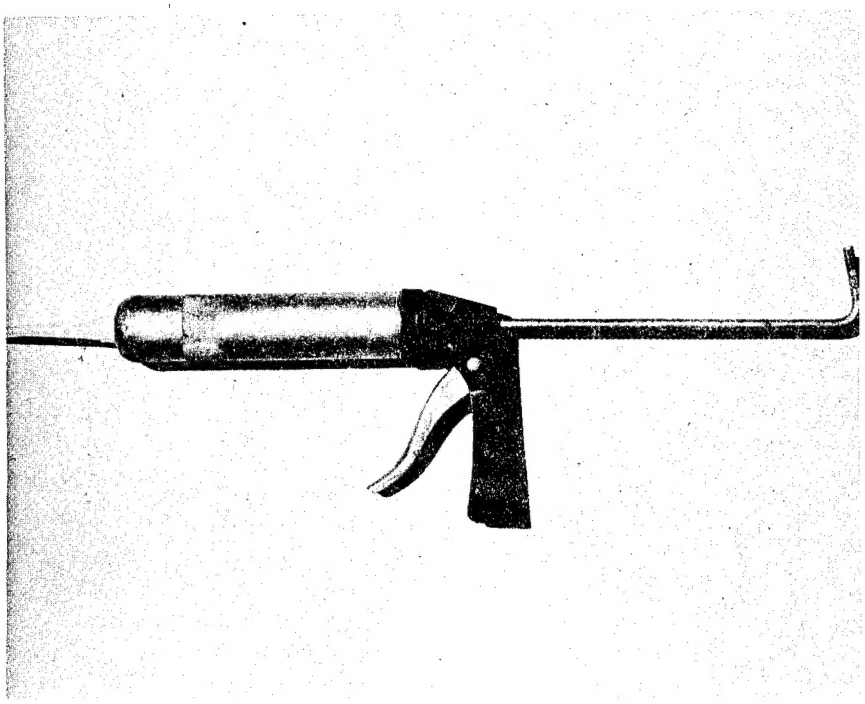

Figure 1 Pressure Grouting Hand Gun

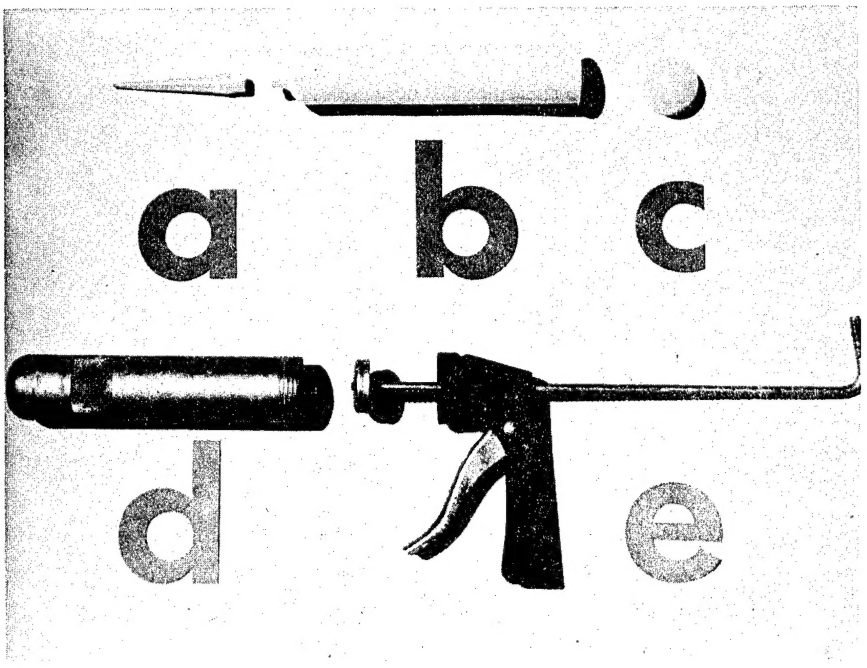


Figure 2 Component Parts of Pressure Grouting Hand Gun

Guns of the type described are less likely to leak epoxy materials when under high pressure and they offer protection to the operator by keeping the cartridge confined so that is is less likely to rupture than types not confined.

The gun is used by first threading a plastic nozzle into the end of the cartridge. The cartridge is then filled to its capacity of one pint (8 fluid ounces) with the mixed epoxy resin compound. Holding the cartridge over a waste container (e.g. empty coffee can) to catch any drippings from the nozzle, the cap is then inserted into the open end. The cartridge is then inserted into the steel cover. This cover is then threaded onto the handle-ratchet-ram mechanism making sure that the ram, which is the full return position, comes into firm contact with the plastic cap. Care should be exercised not to put any pressure into the container by triggering the ram too far forward. The hand gun is now ready for use and it should be used before the pot life of the epoxy has been reached. In the event that the epoxy starts to cure, indicated by undo warming of the steel cover, remove and discard it along with any epoxy left in it. A new, filled, cartridge can then be inserted.

13. Pressure Pot

This method of injecting epoxy compounds employs equipment similar to that used in paint spraying operations. A two gallon heavy viscosity fluid pressure tank capable of operating at 100 psi is recommended for use. Such a tank needs to be provided with an air, or other inert gas, pressure source capable of maintaining a pressure in the tank at all times as great as or greater than that to be used in injecting the epoxy compound. In addition it must be supplied with an air pressure regulator so that precise control of the injecting pressure can be maintained, Figure 3. The line (a) comes from an oil, moisture, and dirt free pressure source. This is connected through the entry valve (b) to the pressure regulator (c) which in turn allows controlled air flow into the tank. The outlet or location where the epoxy compound leaves the tank is at (d). The 3/8 inch outlet is reduced to a 1/4 inch shut off needle valve (e). To the valve is joined a 1/4 inch nipple and 1/4 inch cross (f). The cross provides for three pressure injection lines. Each line is proceeded by a 1/8 inch exit valve (g), the outlet of the 1/4 inch cross having been reduced to 1/8 inch. The epoxy injection line is 1/8 inch inside diameter Imperial Eastman Hylo-Seal 'F' Tubing No. C902-1/8 with a 1000 psi rupture rating. The length of the tubing should be as short as possible and determined by how close the pressure pot may be placed to the cracks being injected. In order to minimize pressure losses in the system, this length should never exceed ten feet. If longer lengths are absolutely required, only one line should be utilized and higher pressures should be considered.

The tank must also be equipped with an emergency pressure release valve (h) which must be adjusted to release at 5 to 10 psi less than the maximum allowable pressure of the equipment. The tank is also equipped with a manual pressure release valve (i).

Figure 4 shows the inside of the pressure tank along with the epoxy compound container. The desired amount* of the mixed epoxy resin compound is placed in a one half gallon plastic food container which is then placed in the pressure tank. A 300 psi flexible rubber feed line (Figure 5), of sufficient length to reach the bottom of the epoxy container, is attached to the inside of the outlet port on the lid of the pressure tank. The lid is placed on the tank making certain the feed line is inside of the epoxy container. The pressure pot is ready for use as shown in Figure 3.

* Section VI, Article 25, discusses amounts to be used.

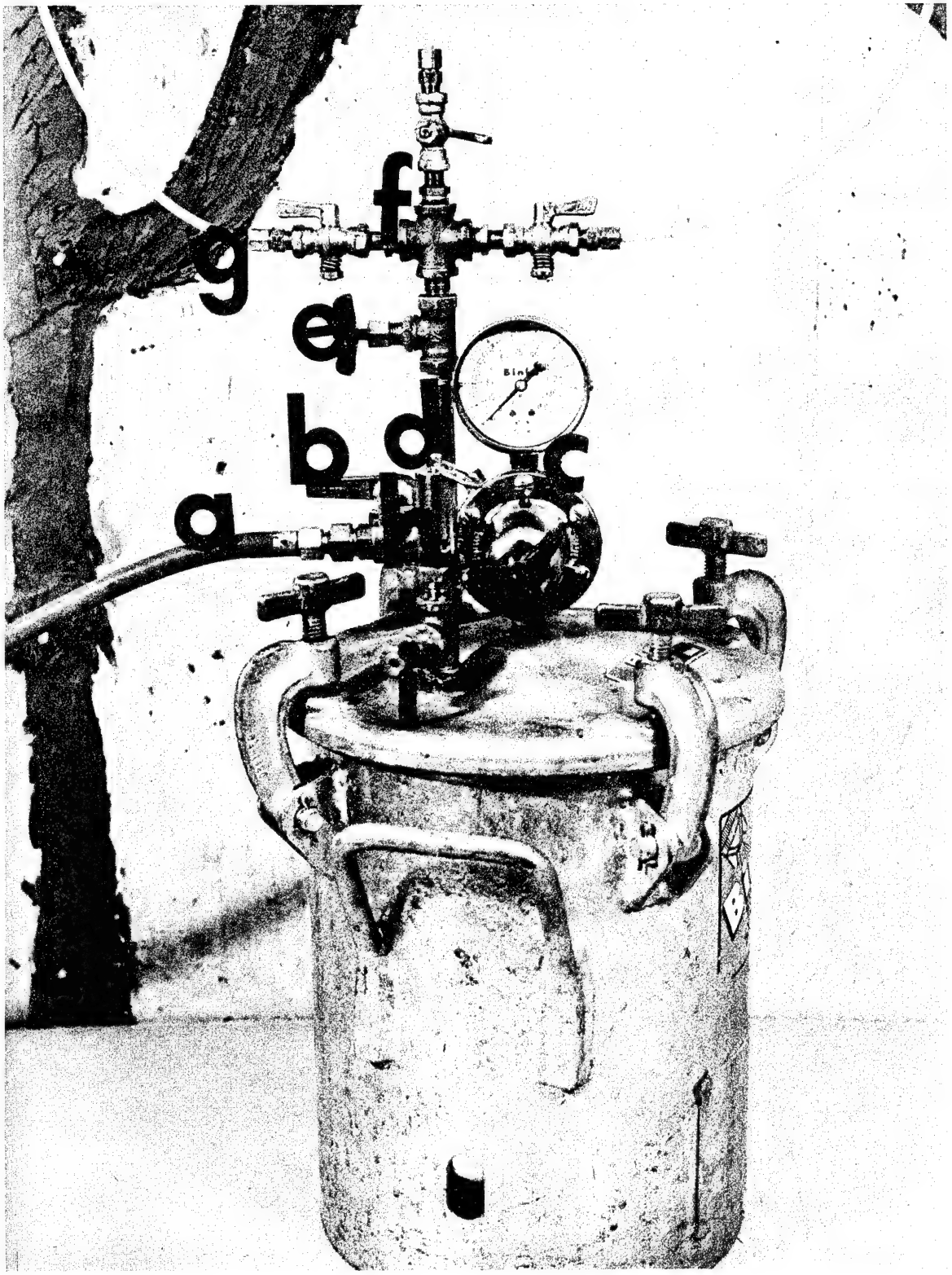


Figure 3 Pressure Pot and Related Grouting Apparatus

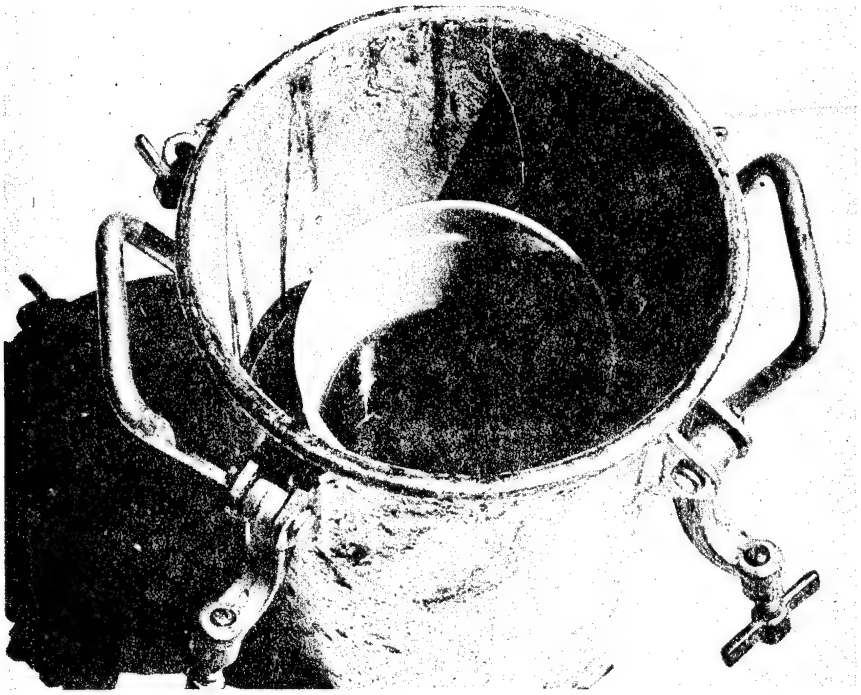

Figure 4 Open Pressure Pot

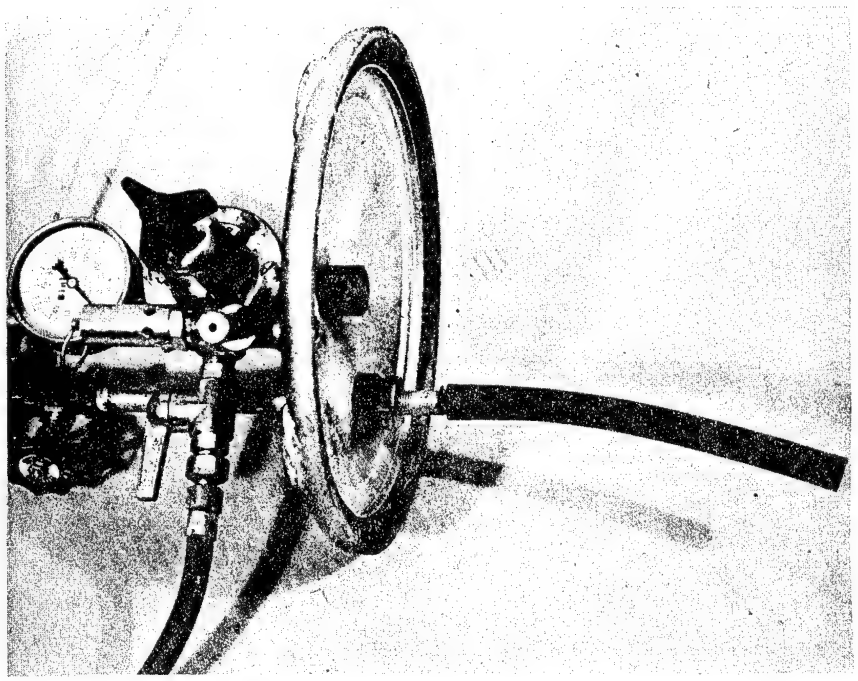

Figure 5 Pressure Pot Lid Showing Flexible Rubber Feed Line

14. Two Component Nozzle Mix Equipment

Several types of equipment have been developed which are designed for the purpose of pumping the epoxy resin and the hardening agent in the proper proportions to a mixing nozzle or mixing head at or near the injection port. This equipment is all proprietary in nature and therefore it is not possible to give any details concerning its makeup.

An important aspect of such equipment is that there is no possible way of knowing for certain what mixture is being injected into a crack. Therefore, the use of this equipment should only be allowed when two control devices are provided. First, quick disconnects from the mixing gun should be provided in order that periodic checks can be made of the proportioning of the epoxy to hardner. The material supplier and the contractor providing the specialized equipment should provide the owner with the proper ratio by weight and/or by volume of the two components as obtained from the hoses disconnected from the mixing gun. This ratio must be checked and maintained within 1% of the specified values no less often than four times during one working day with the first check being made before any grouting operations have commenced.

Second, each component must be color coded in order that a visual examination of the epoxy compound, as it leaves the injection nozzle, will indicate whether proper mixing of the components is being obtained. For example, the resin component might be black and the hardener component might be white so that the resultant mixture becomes a uniform gray. A sample of the epoxy compound can be injected into a pint size container. Improper mixing would be denoted by streakiness and/or by non-uniform coloring.

In the event that either of the above criteria is not met, all pressure grouting operations should cease until proper remedial action has been taken.

## SECTION IV
## PRESSURE GROUTING MATERIALS

### 15. General

There are a variety of epoxy resin compounds available on the market advertised for use as a grouting material. Properties of these materials are generally listed under the headings of components 'A' and component 'B' and the 'cured epoxy' system. In general, these properties are from the known material, physical, and chemical properties of a particular compound.

Most specifications reflect these known values. This might be expected for certain physical and chemical properties. However, material strength properties need special consideration. In this section a specification is given which is based upon fundamental material characteristics of epoxy resin compounds.

### 16. Viscosity

The various epoxy resin compounds used for pressure grouting have a wide range of viscosities. The viscosities are generally listed in centipoises at 77° F (25° C). These values vary from 100 cps to 16,000 cps. The viscosity of each of these materials also varies greatly with temperature. Flow rate of an epoxy compound within a crack under a constant pressure is primarily a function of viscosity. Therefore, cracks should not be grouted when the concrete temperature is below 50° F (10° C).

### 17. Material Properties

Material strength properties of any structural material must be based upon criteria established by material research, by engineering analysis, and by design. Most structural materials do not alter in properties significantly when they are subjected to normal atmospheric environmental temperatures. This is not true, however, for the epoxy resin compounds. These materials exhibit a wide range of material properties throughout the normal temperature ranges to which they are subjected. The specification herein takes into account these changes.

### 18. Specification

The epoxy resin compound shall be a clear two component, 100% solids, compatible system. Component A shall consist of an epoxy resin, 100% reactive, and free from any non-reactive dilutants. Component B shall be a curing agent of the amido-amine class and it shall be free of any non-reactive additives. All parts of component B shall be reactive with component A.

Component A (Epoxy Resin)

| Property | Test Method | Requirement |
|---|---|---|
| Viscosity (Brookfield) @ 77° F (25° C), Centipoise | ASTM: D2393-68 | 1800 maximum |
| Weight per Epoxide | ASTM: D1652-67 | 230 - 280 |
| Color (Gardner-Holdt) | ASTM: D1544-67T | 4 maximum |

Component B (Curing Agent)

| | | |
|---|---|---|
| Viscosity (Brookfield) @ 77° F (25° C), Centipoise | ASTM: D2393-68 | 1000 maximum |
| Color (Gardner-Holdt) | ASTM: D1544-67 | 15 maximum |

Uncured Mixed Epoxy Resin Compound

| | | | |
|---|---|---|---|
| Viscosity (Brookfield) | ASTM: D2393-68 | 77°F | 1300 cps maximum |
| Gel Time @ 77°F (25°C) 100 gm mass in 4 oz. metal container | ASTM: D2471-66T | | 45 minutes minimum |

Cured Epoxy Resin Compound

| | | | |
|---|---|---|---|
| Tensile Strenght[1], psi | ASTM: D638-67 | 32°F | 10000 psi maximum |
| | | 77°F | 3200 psi minimum |
| | | 122°F | 600 psi minimum |
| Tensile Elongation[1], percent | ASTM: D638-67 | 32°F | 5% minimum |
| | | 77°F | 13% minimum |
| | | 122°F | 40% maximum |
| Weight Loss, Percent[1,2] 24 hours @ 266°F (130°C) | ASTM: D756-66 (except temperature) | | 2.0 maximum |

1. All specimens are to cure for 5 days at 77° F (25° C) and then 70 hours @ 122° F (50° C).

2. The specimen size is 1 x 3 x 1/8" bar.

| | | |
|---|---|---|
| Bond Strength, Composite Cylinder, % | Appendix A | 90% minimum of control concrete |
| Shrinkage, Glass Bow, percent | Appendix B | 0.0020 maximum |

## SECTION V
## CRACK PREPARATION

### 19. Introduction

As stated in Section II, cracks which are "working" cracks or "joints" should not be pressure grouted with the materials described in this guide. Instead, reference should be made to joint fillers and sealants. Joints are relatively easy to identify but a "working" crack is not.

All cracks in concrete and masonry open and close with changes in temperature. The size of crack, the amount of movement, and the cause of the crack should be considered as factors for deciding whether or not the crack should be classified as a "working" crack. If it is determined that the crack under consideration behaves similar to a designed expansion joint, the crack should be considered a "working" crack which is not to be grouted under the direction of this guide. Good engineering judgement is required to make this determination.

Once it has been determined that pressure grouting is an acceptable method of repair and/or maintenance, a decision is needed as to the time of making the repair. *All repair must be done when concrete and air temperatures are 50°F (10°C) or greater.* Cracks should be grouted during cooler temperature so that the crack is as "open" as possible under reasonable working conditions.

### 20. Prepare Crack for Sealing

Past work has indicated a great deal of time and effort has gone into crack preparation before applying a surface seal. It has not been proven that this effort was justified. A minimum preparation is all that is required as described in the following steps.

a. To remove dried mud, grease, dust, or other foreign material along the surface of the concrete or masonry, wipe it as clean as possible with a solvent such as methyl ethyl ketone.

b. If any crack has a lot of loose debris in it at the surface, it should be 'blown out' with an oil and moisture free air jet from a 75 to 100 psi source. Any large loose particles should be removed by hand. Also refer to Section II, Article 10.

c. Any large holes or voids in the surface should be filled with an epoxy-sand mortar. This work should be done in accordance with the technical manual TM 5-822-9 except that the epoxy binder should consist of the material herein specified for grouting purposes.

d. If moisture is present as a result of rainfall or other temporary source, the criteria set forth is Section II, Article 5 should be followed.

e. Concrete coatings, such as paint, in general do not have to be removed except loose flakey particles.

21. Entry Ports

After the cracks have been prepared for sealing the next step is to install pressure injection ports.

*The entry ports consist of 3/4 inch lengths of 1/4 inch steel tubing glued to the concrete surface spanning the crack. The inside diameter of the tubing must be such that the flexible pressure line (Nylon Seal C902) slides snuggly inside the steel tubing*. After cutting, the inside at one end is reamed and the other end is ground or filed to assure a flat end.*

When placing the piece of tubing, the unreamed end is coated with 'contact' cement. The cement is allowed to dry for approximately two minutes or until such time that the glue has become tacky enough to hold the fitting on the wall. The coated end is firmly pressed against the concrete or masonry over the crack, Figure 6.

The entry ports must be properly spaced on all cracks. While guidelines can be given for proper spacing, good judgement must be the final criteria. Guidelines for portal spacing are given as follows:

A. Cracks Accessible From One Side

1. For cracks in members two feet and under in thickness, the spacing of portals should not be greater than the thickness of the cracked member. Should it be undesireable to have the epoxy flow out the unaccessible side of the crack, the portals should not be spaced over one-half (1/2) the thickness of the member.

2. For cracks in members over two feet in thickness full penetration of the crack may be difficult to achieve due to limitations of the equipment**. Portals should be not only spaced at a distance equal to the depth of penetration desired, but also at intermediate points in order to monitor the flow of the epoxy as illustrated by the example shown in Figure 8.

3. If the cracks are less than 0.005 inch wide, entry ports should never be spaced greater than six (6) inches apart regardless of the thickness of the cracked member.

B. Cracks Accessible From All Sides

1. For members one foot or less in thickness portals should be placed on the crack on one side only, and spaced according to the guidelines set forth in the preceeding paragraphs (A.1, A.2, A.3).

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* With the flexible line C902 described in Section III, Article 13, steel tubing is "Coil-Part No. 1/4" Bundyflex Tubing, Everhot Products Co., Chicago, Illinois 60641.

** Equipment similar to that which has been herein specified but with higher pressure capabilities (e.g. 150-225 psi) may be required when full depth penetrations are absolutely necessary.

2. For members greater than one foot and less than two feet in thickness, portals should be placed on the crack on all available sides. Portals should be spaced not to exceed twice the distances specified in Articles A.1, A.2, and A.3 above.

3. For members greater than two feet in thickness portals shoudl be placed on the crack on all available sides and spaced according to the guidelines set for is the paragraphs A.1, A.2, and A.3.

C. Location of the First and Last Entry Port

The first and last entry ports should be established at or near the bottom and top of any vertical crack or at the ends of any horizontal crack on a vertical wall or on a horizontal member. Subsequent portals should be established according to the guidelines given above.

D. Surface Sealing of the Crack

After the fittings have been in position for ten to fifteen minutes, the crack surface is completely sealed with a Thixotropic epoxy compound*. In order to withstand pressures exerted by the epoxy as it is being grouted, the thixotropic epoxy seal should be applied with a spatula along the crack to a thickness of 1/16 to 1/8 inch and at the width required to extend the epoxy approximately 1 inch to each side of the crack except at the portals. At these locations the thickness should be tapered to approximately 1/2 inch around the fitting and at whatever width required to achieve the taper. Care must be taken that an excellent seal is obtained around the fittings, as this assures that they will stay in position and that there will be no leakage during the grouting operation, Figure 7.

Often a rapid curing epoxy compound or rapid hardening thermoplastic is used for sealing cracks when rapid grouting capabilities are desired. Unless very special requirements are to be met, these materials are not recommended for use under this guide. If their use is justified, specialists in the epoxy pressure grouting field should be called upon.

After the cracks and fittings have been sealed, and after the epoxy seal has cured (generally overnight), the cracks are ready to be pressure grouted.

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* Thixotropic epoxy compounds can be purchased from most epoxy compound formulators. A material meeting specification MMM 6-650, Grout, Grade C, can be used.

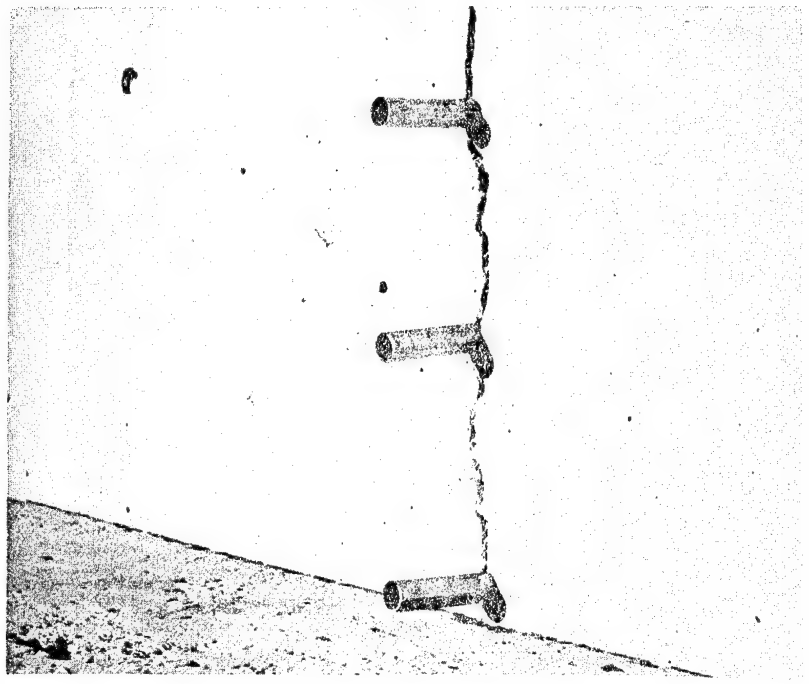

Figure 6 Steel Fittings Glued Over Crack

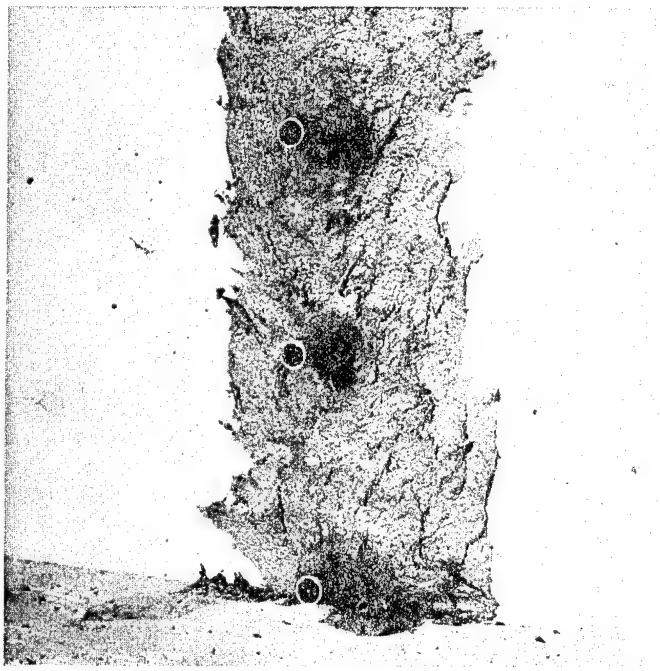

Figure 7 Crack and Fittings Sealed with Thixotropic Epoxy

22. Quantity of Surface Sealing Compound Required

Following the criteria given in Article 21 D, one pint of thixotropic epoxy should be available for each ten lineal feet of crack. It is recommended that the thixotropic epoxy be purchased in pint units. One pint of epoxy should be mixed at a time according to the manufacturers instructions.

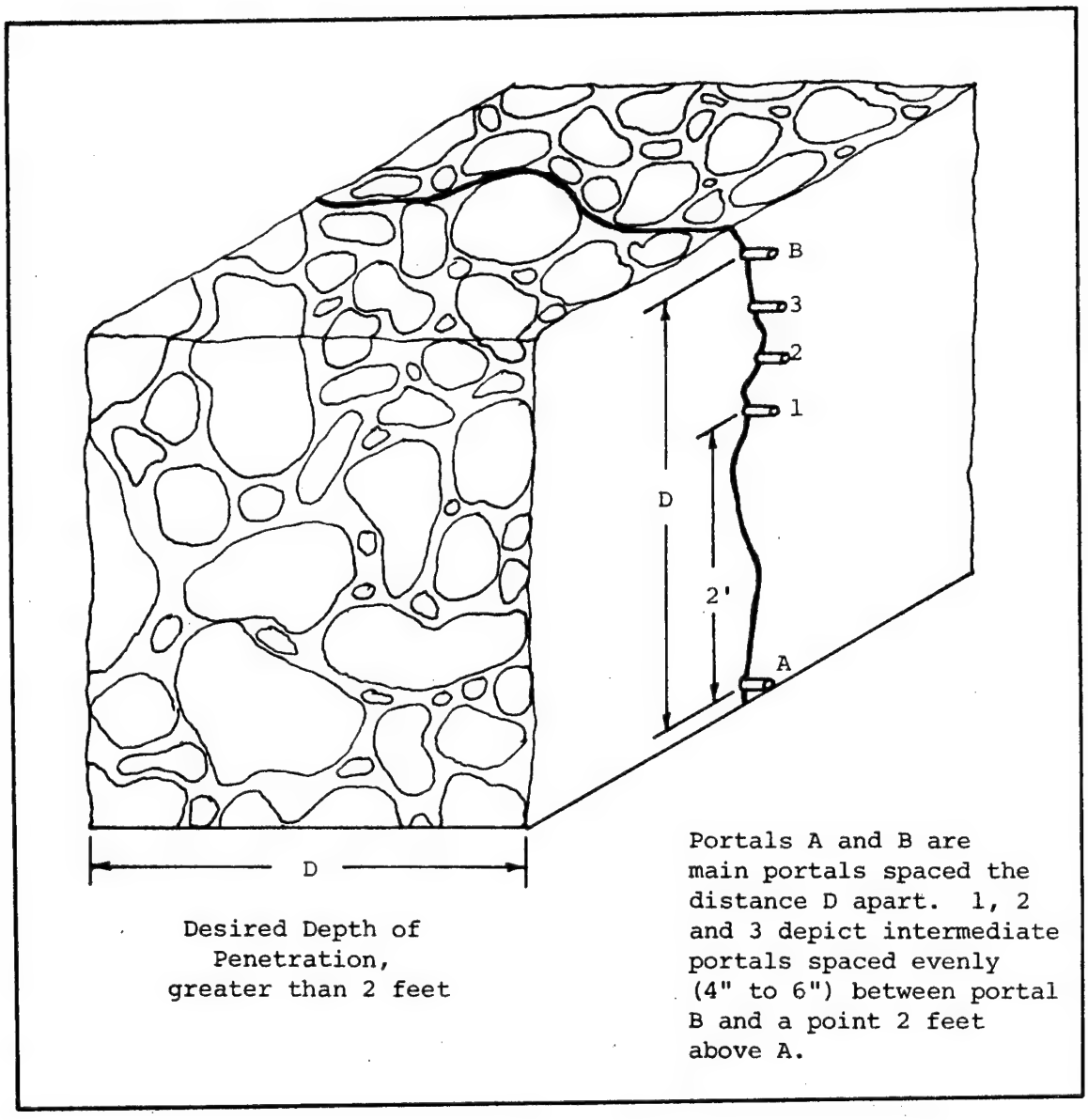


Figure 8 Schematic Illustration of Intermediate Portals

## SECTION VI
## EPOXY INJECTION

### 23. General

Before pressure grouting operations commence, all required epoxy grouting materials and equipment should be made available on the job site. The selection of the equipment can be made according to Section III. This section discusses determination of the quantity of grout required and the method by which it is applied.

### 24. Quantity of Grout Required

An estimate of the amount of epoxy grout which will be required for any given job can be calculated using the following formula

$$Q=0.7DLW, \text{ where}$$

Q is the quantity of epoxy grout required in pints,
D is the desired depth of penetration in inches,
L is the lineal feet of crack to be grouted, and
W is the crack width in inches.
.7 is a constant taking into account waste and other unpredictable factors.

The epoxy grout should be obtained in one pint units and each unit, when being made ready for use, should be thoroughly mixed according to the manufacturer's instructions.

### 25. Quantity of Grout to be Mixed

a. Hand Gun

When the caulking hand gun has been selected for use, one pint of grout should be mixed at a time. The gun is then filled in accordance with the procedures outlined in Section III, Article 12.

b. Pressure Pot

The amount of epoxy grout to be mixed and placed in the pressure pot at any one time is determined by the width of the cracks being grouted as shown in the following table.

| Crack Width | Quantity |
|---|---|
| 0.003 to 0.010 inch | 1 pint |
| 0.010 to 0.020 inch | 2 pints |
| 0.020 to 0.250 inch | 3 pints |

The above quantities are based upon the following criteria: pot life and flow rate. Pot life is the length of time after mixing which a given quantity of epoxy can remain in a given container before it begins to gel. The larger the quantity the shorter the pot life. In addition, pot life is a function of air temperature - the higher the temperature the shorter

the pot life. The flow rate is the amount of epoxy which can be injected into a crack per unit of time - the smaller the crack the lower the flow rate.

As can be determined from above, the widest cracks will receive the most epoxy in a given length of time. Therefore, within pot life limitations, large volumes can be mixed when grouting into wide cracks. The above table can only serve as a guide. After work has commenced, it may be found desireable to make adjustments to the quantity mixed and placed in the pressure pot. For example, a wide crack may accept 3 pints of grout in such a short time that more time may be spent in recharging the pressure pot than in actual grouting. Therefore, an increase in the amount of grout initially placed in the pot would be justified. However, the increase in quantity will shorten the pot life.

26. Grouting Procedures

a. Pressure Pot

The desired quantity of epoxy grout is mixed in a one half gallon plastic container and placed in the pressure pot. After making sure all exit valves are closed, the pot is pressurized. Each of the injection flow lines is inserted into an entry portal. Each line should go to the bottom portal of a vertical crack or to an end portal of a horizontal crack. *In order to insure continuity of the injected material within the crack, it is recommended that each continuous crack be grouted utilizing only one injection line.*

After the lines have been placed, the exit valves are opened to start flow of the epoxy into the cracks. Flow of the epoxy can be monitored by watching the movement of small air bubbles in the line. Generally a few small bubbles can be found. If none are present, bubbles can be introduced by closing the exit valve for the desired line, removing and then replacing the line. When the exit valve is opened, an air bubble will appear. Each line is left in place until the epoxy starts to flow out of the adjacent portal. When this happens the exit valve controlling that particular line is closed. The injection line is moved to the next portal and the portal just used is plugged. However, if intermediate portals have been poaced as discussed in Section V, Article 21-A.2, the injection line is not moved until the epoxy grout reaches the portal spaced at the desired depth of penetration. As the epoxy appears at each intermediate portal, the portal is plugged. In the case that flow ceases before the grout reaches the desired portal, the injection line should be moved to the next portal which has not been plugged, (Figure 9).

Portals are plugged by inserting a one inch length of a standard 3/16 inch wooden dowel. The doweling of the type required is available at most paint and art stores, hobby shops, or lumber yards.

The grouting process should be a continuous operation and interruptions must be kept to a minimum. To minimize the time required to replenish the epoxy in the pot, a new batch should be mixed approximately 5 minutes prior to the pot life. As soon as the new batch of epoxy grout has been mixed, the

Figure 9 Epoxy Injection Line and Plugged Portals

grouting operation is stopped by shutting off the pressure entry valves and the epoxy exit valves, (Figure 3). The tank then is depressurized by opening a pressure release valve. *Never attempt to depressurize by removing the lid.* When the gauge pressure reaches zero, the lid is opened and the epoxy container is removed and discarded. The new container of freshly mixed epoxy is placed in the tank. The lid is replaced and secured, and the tank is pressurized. Before resuming the grouting operation, the old epoxy should be bled from the lines. This is done by removing all lines from the portals, holding the ends of the lines over a waste container, and opening the epoxy exit valves. The lines are bled until the old epoxy has been completely removed. This is indicated by the presence of large air bubbles which are automatically entrapped between the old and fresh epoxy during the change over. Once the fresh epoxy has reached the end of the lines, the exit valves are closed, the ends of the lines are replaced in the portals, and the exit valves are opened.

Should the supply of epoxy grout in the pressure vessel be depleted before the pot life is reached, fresh epoxy should be mixed as rapidly as possible. The same procedure as outlined above is used for recharging the pressure pot.

Any delay in the pressure grouting operation (e.g. lunch break, quitting time, etc.) over fifteen (15) minutes in duration demands that the pressure pot be cleaned and all lines thoroughly cleared of epoxy compound. This is accomplished by placing a full container of toluene, methylethyl ketone or other recommended solvent in the pot which is then pumped through all lines into a waste container. This process is then repeated with a one half full container of solvent. This process will leave the equipment ready for reuse.

b. Hand Gun

The hand gun is prepared and filled as outlined in Section III, Article 12. Approximately 1/4 inch is cut off of the end of the plastic nozzle; and to inject epoxy, the end of the plastic nozzle is inserted into a portal opening. The gun is held firmly in place and pressure is applied to the epoxy by squeezing the handle, (Figure 10). Flow of the epoxy can be monitored by watching for the movement of air bubbles in the plastic nozzle. The same sequence of injecting into the portals is used as described above.

27. Extending the Pot Life

Before any pressure grouting operations begin, the pot life of the epoxy material at the temperatures likely to be encountered at the job site should be determined. If the manufacturer's literature does not give such information, one field test should be performed. A two pint quantity of the epoxy grout should be mixed in a half gallon plastic container during the warmest part of the day. The time from mixing to gelling should be noted and used as the pot life.

If a longer pot life is desired, it may be extended by placing the pressure pot in a tub of ice and by shading all apparatus from direct sunlight.

In the event that the hand gun is being used the pot life can be extended by cooling the individual epoxy components before mixing.

In either case, the components or mixed compound should not be maintained at temperatures below 50° F (10° C).

28. Determination of Success

Core drilling is the best method for determination of the effectiveness of repair. However, besides being costly, this method is not always practical.

Therefore, close observation and inspection of the work as it progresses is imperative. Although it is difficult to determine if a crack has been filled to the desired depth of penetration, it is relatively certain that a high degree of success will be obtained if the procedures outlined above are followed.

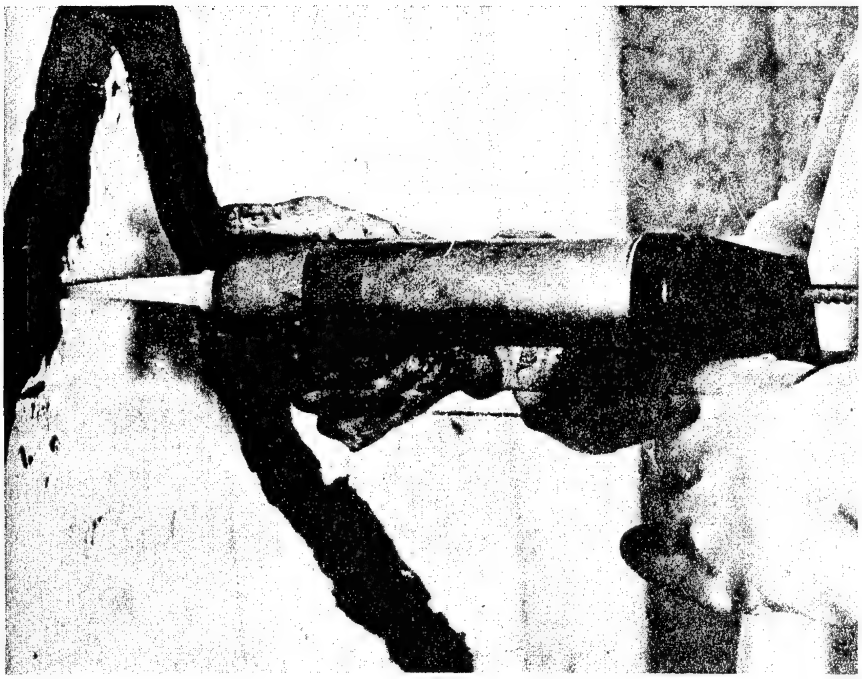

Figure 10 Grouting With a Hand Gun

## SECTION VII
## CLEAN UP

### 29. General

At all times any spillage of epoxy materials and solvents should be immediately cleaned as they represent both health and safety hazards.

Epoxy materials are wiped up with clean rags soaked in methylethyl ketone, toluene or other solvent with clean dry rags. The rags are then put in disposable containers and removed from the job site.

All empty epoxy component containers should be immediately placed in leak proof waste containers.

### 30. Cleaning the Pressure Pot and Hand Gun

At the end of each days work or at the completion of a job, methylethyl ketone, toluene, or other recommended solvent should be flushed through the pressure pot and lines as described in Section VI, Article 26. After a job has been completed and the equipment is not to be used for some time, it is advisable to completely disassemble and clean the equipment prior to storage.

The hand gun should be thoroughly cleaned with solvent each time a cartridge is removed.

### 31. Cleaning the Concrete or Masonry

After a crack has been completely injected and the adhesive has cured; the surface seal, fittings, and any spillage must be removed from the wall, slab, or other surface. The injection fittings can easily be knocked off with a hammer. The remaining epoxy can be removed by grinding. While almost any grinder will suffice, a typical high speed hand grinder with a rigid abrasive disk suitable for grinding concrete is recommended. *Safety glasses or goggles and a respirator should always be worn when performing this operation.*

## SECTION VIII
## SPECIAL PROBLEMS

### 32. General

As with all types of construction jobs, occasional problems arise which can bring about undue time delays and affect the outcome of the job. After pressure grouting has commenced, any extended delay may result in the curing of the epoxy which has been injected into the crack. If the crack has not been filled, it may be impractical, if not impossible, to ever gain access to the unfilled portion. Therefore, time delays must be prevented.

This section will review several of the more common type problems causing time delays and their solutions.

### 33. Equipment Breakdown

At least one and preferably two spare pressure pots and hand guns with all valves, lines, and accessories should be at each job. In case of problems, a spare set can be put into operation while repairs are being made.

If feasible, an emergency air pressure source should be at each job location since a shut down could effectively ruin part of the job. In the event of the loss of the air pressure source and no spare is available, the job can be completed with the use of hand guns.

### 34. Epoxy Cures in the Pressure Pot

Until a certain level of proficiency in the use of the pressure pot apparatus has been obtained, there is a high probability that at times the epoxy grout will cure within the pot. The most obvious indication of this occurrence would be stoppage of flow in all injection lines along with heating of the metal portions of the grouting hardware.

The apparatus specified in this guide has been designed with the removable feeder tube as described in Section III, Article 13, so as to minimize the inconvenience caused by such an occurrence. Since the large mass in the pressure pot will gel and cure much sooner than the material in the lines, all that is normally necessary is to remove the epoxy and its container from the pressure pot along with the flexible feed line. A new feed line can be quickly installed. Then methylethyl ketone should be flushed through all lines into a waste container until free flow through all lines is obtained. After this has been done, a new mixture of epoxy can be placed in the pot and the pressure grouting operation restarted.

### 35. Leakage Around an Entry Port in the Crack Seal

Occassionally leaks will appear in the epoxy crack seal most often near or around an entry port. The most foolproof method of sealing a leak

is to first wipe the surface clean with a rag soaked in methylethyl ketone and then to coat the area over and around the hole with a rapid curing epoxy compound*.

A less expensive method of stopping small leaks would be to vigorously rub paraffin wax into the hole. Oftentimes a small wooden peg or splinter can be driven into a hole to stop leakage. In any case, as soon as the leak has been stopped, pressure grouting should be resumed.

36. Blocked Entry Port

Occassionally an entry port is encountered which is blocked. A very small diameter sharply pointed awl and an air jet can be used in an attempt to open the entry port. If opening the port is not possible, and if there are sufficient entry ports along the same crack, it is best to bypass that particular port in the grouting operations.

If access to the blocked port is essential, then grouting operations on that particular crack should cease and the entry port and the surrounding crack seal removed. A new access point should be found, if possible. Grouting operations should not be resumed on the crack until a new entry port has been established and the crack resealed.

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* Rapid curing two component epoxy compounds which cure in less than five minutes are available in small tubes in most hardware and variety stores. Special one component Jeweler's epoxy cements are also available, such as H. R. Superior, Quick Set Jewelers Cement.

## SECTION IX
## CONTROL TESTS

### 37. Field Control - Compression Tests

Just as concrete cylinders are made at a job site to check the quality of the concrete delivered and placed, specimens should be taken of the epoxy resin compound for making control tests. These tests should become an intregal part of any job since it is the only non-destructive way of assuring that quality epoxy has cured within the grouted structure.

The specification for the grouting material does not include a compressive strength requirement. Nevertheless, the accepted material will exhibit definite stress-strain characteristics at a given temperature. These should be determined at 77° F (25° C) after curing for 5 days at 77° F (25° C) and then 70 hours @ 122° F (50° C).

In the field one compressive test specimen should be taken from every fifth batch of formulated epoxy compound. This is done by filling a specimen mold from a pressure line. Such a mold is shown in Figure 11. This mold is made by pouring a Dow Corning Silastic RTV mold-making rubber over one inch diameter by two inch long aluminum cylinders as shown in Figure 12. After filling the mold the epoxy should be allowed to take an initial set before removing from the job site. At this time the specimen can be removed from the mold and placed in a curing room. After curing, the specimen should be tested in compression in accordance to ASTM D695-63T. The compressive stress-strain curve of the specimen should not deviate over 15% from the control stress-strain curve.

### 38. Nozzle Mix Equipment

In the event that nozzle mix equipment is to be used on a job, quick disconnects must be provided near the mixing chamber. No less than four times during one working day the lines must be disconnected and free flow from both the epoxy and hardener lines must be obtained in pint size containers of known weight. When one container is nearly full, both containers are weighed. The proportioning by weight of hardening agent to the epoxy resin must not vary by more than one percent (1%) of that specified.

In addition, compression test specimens must be taken as described in Article 37.

### 39. Core Drilling

Cores are sometimes desired for making an evaluation of the epoxy penetration within the cracked structure.

### 40. Flow of Grouting Material

As has been indicated in earlier sections of this guide, flow of the epoxy grout is essential. Inspection must continually be made of the transparent

injection lines or the plastic hand gun nozzle, watching for the movement of small air bubbles. Movement of the air bubbles assures flow is taking place.

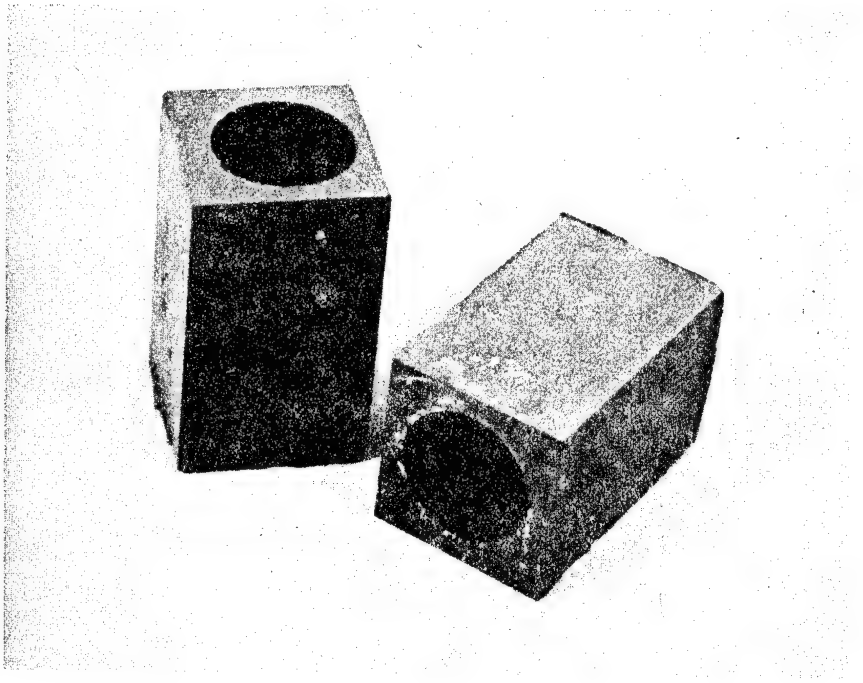

Figure 11 Silicone Rubber Compressive Specimen Mold

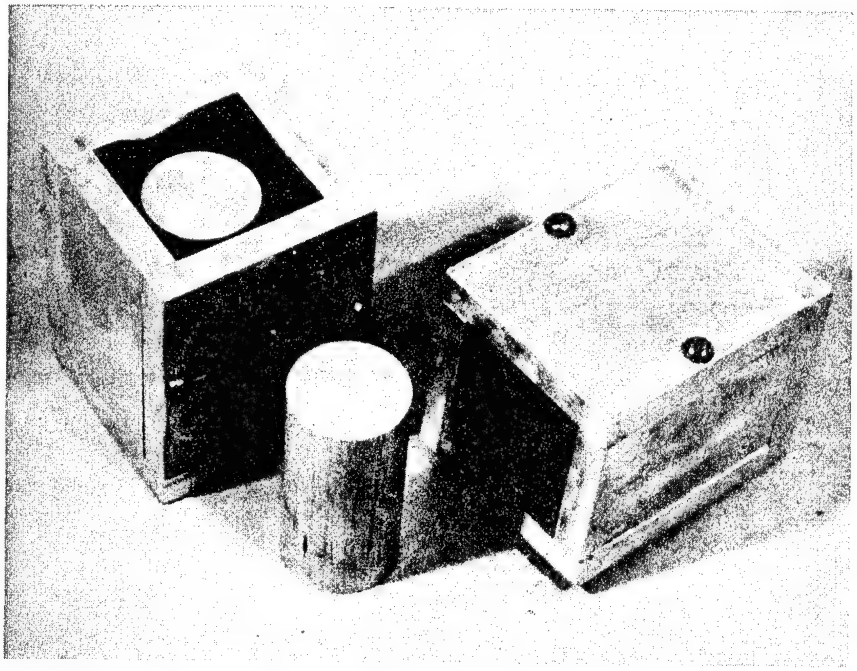

Figure 12 Steel Molds for Making Silicone Rubber Molds

## SECTION X
## SAFETY AND HANDLING PRECAUTIONS

### 41. Introduction

While instances of serious accidents in connection with the use of epoxy compounds are rare, a danger does exist. This section, therefore, takes on a roll of extreme importance.

In March, 1971 the American Concrete Institute Committee 503, Adhesives and Bonding Agents, reviewed and generally accepted a draft of a chapter on the handling precautions of epoxy resin compounds. This chapter is to be included in the Committees recommended practice for use of epoxy resin compounds.

This chapter on safety represents the efforts of many experts in the epoxy field. It is, therefore, included as part of this guide with only minor changes.

### 42. General Hazards

Just as there are proper, safe practices for handling lime, acid, portland cement, etc., there are also precautions which should be observed when handling epoxy resins and materials used with them.

A number of different basic epoxy resins can be combined with an even greater number of curing agents, flexibilizers, fillers and other chemicals to produce several hundred different end products with various combinations of the unique properties listed elsewhere in this guide. This versatility, which makes the epoxies so useful, also contributes to handling problems for the user (and, indeed, the manufacturers) of epoxy products. On the one hand, most epoxy formulations are non-hazardous even when carelessly handled; on the other hand, there are a few formulations which are extremely hazardous when handled improperly...and in between are compounds with varying degrees of hazard.

Two typical health problems which may be encountered when epoxy materials are carelessly handled are:

a. Skin irritation, such as burns, rashes, itches, etc.

b. Skin sensitization, which is an allergic reaction similar to that caused in certain people by wool, strawberries, poison ivy, etc.

It should be noted that sensitization reactions may sometimes occur immediately, but at other times they occur only after long periods of continual exposure. Workers should guard against the possibility of delayed sensitization or of thinking that they are immune to sensitization.

The variety of the epoxy compounds marketed today makes it essential that the labels be read and understood by those people working with epoxy

products. The Society of the Plastics Industry, Inc., Epoxy Resin Formulators Division has produced a "Guide for Classifying and Labeling Epoxy Products According to their Hazardous Potentialities" to aid in the safe use of epoxy products. Most resin suppliers, as well as formulators, will label their products according to this guide. Copies are available through the Society of the Plastics Industry, Incorporated, 250 Park Avenue, New York, New York 10017.

43. Safe Handling

Safe handling of epoxy materials can be accomplished by:

a. Working in a well ventilated area. As with most chemicals, storage of materials should be below eye level.

b. Using disposable equipment wherever possible; disposable suits and gloves, available from many suppliers of work garments, are suitable for this use. Disposable rubber or plastic gloves are recommended. These should be discarded after use. Cotton or asbestos gloves, if used, should never be re-used if they have become soiled with epoxy compounds.

c. Careful attention to personal cleanliness and protection. Safety eye-glasses or goggles are strongly recommended, both when handling epoxy compounds and acids. Involuntary habits such as face scratching or eye-glass adjustment should be avoided. For similar reasons, handling important tools, eating or smoking should not be done until the individual has "washed up". When wearing soiled gloves, the workers should avoid touching door handles and other equipment which may later be touched by a person not wearing gloves.

44. After Exposure to Direct Contact

In case of direct contact:

a. To the clothing--Remove soiled clothing at once and change to clean garments. If the soiled garment cannot be thoroughly cleaned, it should not be re-used.

b. To the body--Shower immediately with soap and water to remove spilled epoxy compounds from the body.

c. To the eyes--Flush out with large amounts of water, followed by immediate medical attention. (Safety goggles will usually prevent getting chemicals into eyes.)

d. Anywhere--Do not use solvents other than soap and water or water soluble proprietary cleaners. Most solvents merely dilute the epoxy compounds, aiding them in penetrating the skin. At the same time, solvents tend to dry out the skin and any subsequent exposure is more likely to cause problems.

e. Precaution--Keep soap and water available on all jobs for immediate

cleansing purposes.

45. Use of solvents

While the epoxy compounds usually considered for concrete applications within the scope of this manual are solvent free, the use of solvents may be indicated as a convenience for clean-up of equipment and areas on which epoxies might be spilled. The solvents used will require additional precautions depending on the characteristics of the type used. It is generally true that solvents should not be used to remove epoxy products from the skin since they promote more intimate contact resulting in a greater chance for dermatitis. The following hazards might be encountered in the use of solvents and should be taken into consideration:

a. Flammability and explosion hazard

Many solvents have low flash points and should be avoided. If used, ventilation should be adequate, equipment should be grounded and smoking or other fire initiating devices should be barred from the area of use. Use of low flash-point solvents is <u>not</u> recommended and should be avoided.

b. Vapor hazard

Most solvents have some degree of volatility and the vapors can be toxic when inhaled. Avoid using solvents which may be harmful.

c. Contact hazard

Some clean-up solutions contain phenols or other very aggressive materials which can cause burns or other serious effects when contacting any part of the body directly or indirectly. Use such materials with great care following the recommendations of the supplier. It may be emphasized that when using a solvent, the combined hazards of both the solvent and the epoxy compound are encountered.

46. Education of Personnel

No amount of equipment, however, will substitute for worker education. Those involved in using epoxy materials should be thoroughly informed of the characteristics and hazards of the particular materials they must handle. Not only label instructions but also the manufacturer's literature should be reviewed and pertinent information passes on to each worker. The handling of epoxy materials is not a dangerous occupation as long as reasonable care is taken and personnel and equipment are kept clean. Instances of sensitization are rare but the possibility of a burn, a damaged eye, or other loss-of-time accidents makes knowledge and observance of safe handling practices absolutely essential.

## APPENDIX A

## METHOD OF TEST FOR BOND STRENGTH OF EPOXY RESIN SYSTEMS USED WITH CONCRETE COMPOSITE CYLINDER TEST

1. Scope

1.1 These methods cover the determination of the bond strength of epoxy resin base bonding systems for use with portland cement concrete. The methods cover bonding hardened concrete to hardened or plastic concrete.

2. Discussion of Method

2.1 The specimen is a standard 6 x 12 in. concrete cylinder with a diagonal bond line of epoxy compound joining the two portions of the cylinder at a plane of 30 deg from the longitudinal axis as shown in Fig. A1. The "composite" cylinder is tested in compression just as the standard cylinder is tested. If the composite cylinder has a strength of 90 percent of that of a homogeneous standard cylinder, the epoxy compound is rated adequate for use with concrete of that strength. Actually, often the composite cylinder exceeds the strength of the standard cylinder by 10 to 15 percent because of the reinforcing effect of the epoxy layer.

Half of a composite cylinder is made by placing a specially made elliptical plate in the standard cylinder mold in such a position that it bisects the cylinder equally at an angle of 30 deg from the longitudinal axis. Concrete is cast into the mold and is vibrated or rodded into place. Three standard 6 x 12 in. control cylinders are also made. After 7 days of curing at 100 percent relative humidity, the half-cylinder is dried for 3 to 4 hours. The sloping face is then given either the surface treatment to be used in practice or treatment with a 10 percent solution of hydrochloric acid, sandblasting, or scarification of some sort. In the acid-etching method the acid must be thoroughly washed from the surface and the cylinder dried. An air jet may be used to speed the drying.

When bonding plastic concrete to hardened concrete the cylinder mold is then lined with waxed paper and the half-cylinder is placed in the bottom. Then the cylinder is tilted so that the surface is horizontal, and the epoxy compound is applied to it in an even coat. The epoxy thickness recommended by the manufacturer of the epoxy compound should be used. Next a layer of fresh concrete is placed over the epoxy compound, taking care not to allow pieces of large aggregate to become lodged in the toe. The mold is then stood upright and the remaining space is filled with concrete, which is vibrated or rodded into place. Three additional standard control cylinders are made. The cylinders are then cured until the control cylinders show that the concrete has achieved a desired strength, such as 5,000 psi. The composite cylinders are then tested.

When bonding hardened concrete to hardened concrete, two half cylinders

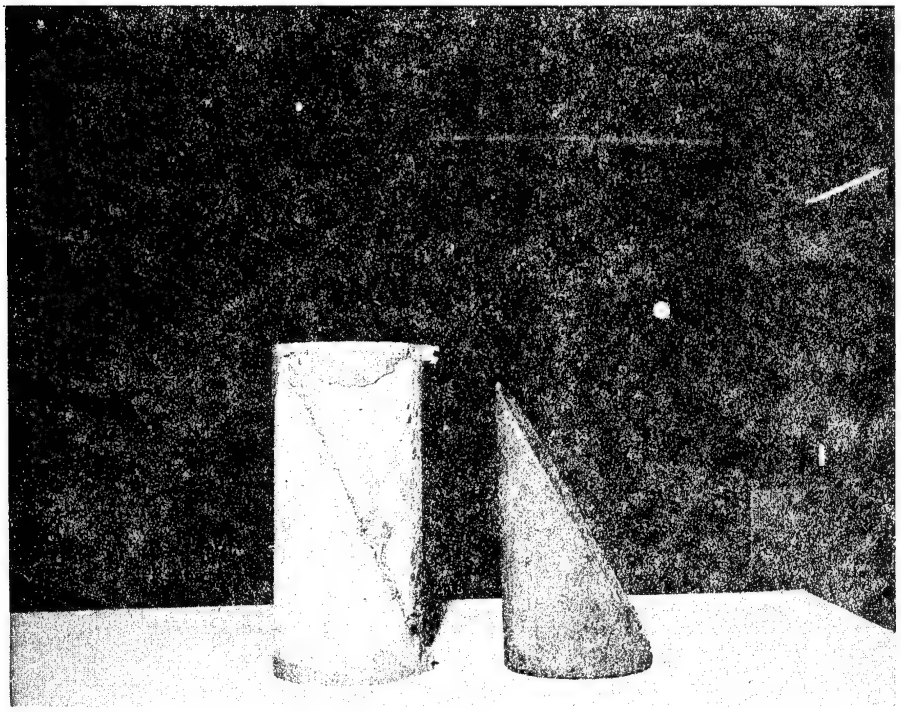

Figure Ala Typical Composite Cylinder Showing Bone Line and a Half-Cylinder

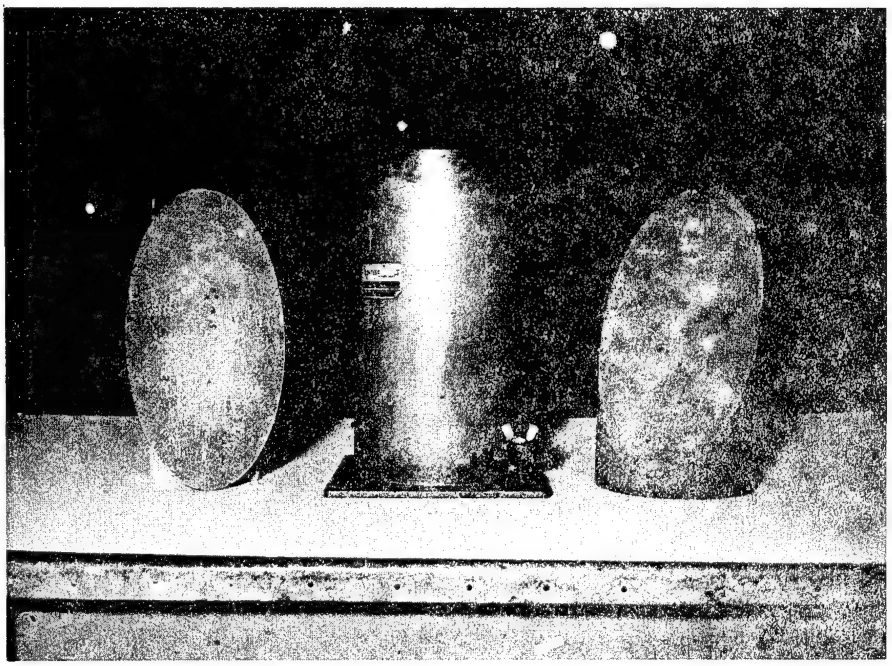

Figure Alb Apparatus for Making Composite Cylinders and Typical Half-Cylinders: Elliptical Steel-Plate Mold Insert, 6 x 12 in. Standard Cylinder Mold, and Completed One-half Concrete Cylinder

prepared as described above are bonded together in such a manner as to make a 6 x 12 in. cylinder. The epoxy is allowed to cure and then the composite cylinder is tested in compression.

Usually three composite cylinders are made for each compound to be tested. At the same time three "mate" (control) cylinders are cast from the same batch of concrete for purposes of comparison. If several epoxy compounds are to be compared, enough equipment must be available to cast three composite cylinders from the same batch of concrete for each compound.

3. Apparatus

3.1 Three standard 6" x 12" concrete test cylinder molds for control specimens.
3.2 Three 6" x 12" molds for each compound to be tested.
3.3 Three elliptic plates for each compound to be tested.
3.4 Tamper or vibrator.
3.5 Small trowel.
3.6 Twelve inch roll of wax paper.
3.7 Ten percent solution of hydrochloric acid.
3.8 Concrete mix with large aggregate less than 1".
3.9 Bonding compound.

4. Procedure for Making Cylinder Halfs

4.1 Place elliptic plate in mold, spacing it so that it will divide the cylinder in half.
4.2 Fill portion of mold above the plate divider with concrete mix. Vibrate and smooth top even with top of mold*.
4.3 Cure first half of specimen 7 days at 100 percent humidity.
4.4 Allow first half of specimen to dry 3 to 4 hours, then coat the elliptic surface of the concrete cylinder with 10 percent hydrochloric acid solution. After solution ceases to react, wash surface thoroughly with fresh water and allow to dry. An air jet may be used to speed drying.

5. Procedure for Bonding Plastic Concrete to Hardened Concrete

5.1 Line inside of mold with a layer of wax paper. Place first half of specimen in mold with round end against the bottom.
5.2 Tilt mold so that elliptic surface of concrete is horizontal and place a support under mold at this position. Apply an even layer of bonding compound to the entire elliptic surface.
5.3 Place a layer of concrete over the bonding compound, taking care not to allow large aggregate to become lodged in toe, then stand mold upright and fill mold with concrete. Vibrate and smooth the top.
5.4 Cast three control cylinders from same concrete mix used for upper half of specimen.
5.5 Cure composite cylinders and control cylinders 14, days, then test.

---

* Three control sylincers cast with the concrete mix used for this first half of specimen could be made if there may be any reasonable doubt that this concrete will bo of lower strength than the concrete poured under part 4.7 of procedure.

6. Procedure for Bonding Hardened Concrete to Hardened Concrete

6.1 Select two half cylinders made and prepared as described in Section 4.
6.2 Bond the two half cylinders along the prepared surfaces making a 6 x 12 in. cylinder
6.3 Test the composite cylinder after the epoxy has cured.

7. Material Bond Rating

7.1 Divide the average failure load of the test specimens by the theoretical failure load a concrete cylinder of specified strength. Multiply this value by 100 to get percent rating; or,
7.2 Divide average failure load of the specimens by the average failure load* of the control cylinders. Multiply the value by 100 to get percent rating based upon the strength of the concrete used.

Note: 7.1 is recommended for use when determining rating for bonding hardened concrete to hardened concrete. 7.2 is recommended for use when determining rating for bonding plastic concrete to hardened concrete.

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* The average failure load is determined from the strength of the control cylinders cast under parts 4.7 and 4.8 is no control cylinders were made for part 4.2. However, if control cylinders have been made for both halves of specimen, the lowest average should be used as the average failure load in computing the rating.

## APPENDIX B

## CORPS OF ENGINEERS TEST METHOD
## EFFECTIVE SHRINKAGE

Suitable forms shall be made on a substantial polyethylene sheet, by using polyethylene strips 1/8 inch deep, to provide a space the inner dimensions of which are 3 1/2" by 9 1/2" by 1/8" deep.

The epoxy components are conditioned to 77° F (25° C) and a 350 gram batch hand mixed for 5 minutes using care to avoid inclusion of air. The mixed components are slowly poured into the forms (a 350 gram batch makes 2 panels) using a slight excess.

Immediately a 4" by 10" panel of single strength glass, meeting Federal Spec. DD-G-451a, type II Clear Sheet Glass which has been thoroughly cleaned with a detergent and water, flushed, and then carefully wiped two times with a clean cloth, moistened with methylethyl ketone, is slowly lowered into place to avoid air bubbles at the epoxy/glass interface.

The glass is then weighted, and cured for 24 hours at room temperature (73° to 77° F) (22.8° to 25° C) before removal from the form. This should provide a laminate of the glass panel and a 1/8" film of epoxy, the dimensions of the epoxy being 1/4" less on all sides than the dimensions of the glass panel.

The panel is then aged one week under conditions of ASTM E-41 57T, 2 (B) which is 77° F (25° C) and 40% relative humidity. At the end of one week, the panel is cycled 30 minutes at 125° F, followed by 30 minutes at the standard temperature in the ASTM method.

At the end of 10 uninterrupted cycles, the panel shall be brought to the standard temperature. One end is then held firmly against a plane surface, and the divergence from plane at the unconfined end shall be measured. Tentatively, this divergence shall not exceed 1/16 inch after the completion of ten (10) uninterrupted cycles.

Since some specifications show Effective Shrinkage in percent, it is desirable that a standard method of computation be followed. We have arbitrarily set the following method for computing the Effective Shrinkage from the measured divergence.

$$S = 100 - \frac{\sqrt{(5)^2 - (a/2)^2}}{5} \times 100$$

where
S = Effective Shrinkage, in percent
a = Measured Divergence, in inches
5 = One-half the length of the glass plate, in inches

APPENDIX C

WORKMAN'S GUIDE: EPOXY PRESSURE GROUTING

1. Introduction

The following is a step by step procedure guide for pressure grouting cracked concrete and/or masonry structures with epoxy resin compounds. This guide is not intended for use in design and planning but is intended to facilitate field operations. This guide is to be used by field maintenance personnel as a check list for equipment and procedures.

Reference is made throughout to the corresponding sections of the manual.

*SECTION X, 'SAFETY AND HANDLING PRECAUTIONS'*

*MUST BE READ AND UNDERSTOOD BY ALL PERSONNEL*

2. Required Equipment

a. Epoxy injection apparatus including all spare fittings, plastic inserts, tubing, etc. (Section III and Section VIII, Articles 33)

b. Epoxy crack sealing materials. (Section V, Article 22)

c. Epoxy grout materials. (Section IV and Section VI, Article 24)

d. Portable electric hand mixer for mixing epoxy components.

e. One half gallon plastic containers. A minimum of one container for each pint of epoxy.

f. Steel fittings for injection ports. (Section V, Article 21). Quantities as specified by job estimator.

g. 1" x 3/8" diameter wooden dowel plugs. (Section VI, Article 26). Same quantity as steel fittings.

h. Five gallons (per day) of methylethyl ketone or acetone or other suitable solvent.

i. Several 20 gallon plastic or galvanized waste containers with lids.

j. Rags, ten pounds or more.

k. Tools, sufficient types and quantity to work on all equipment.

l. Three pairs of rubber gloves for each workman.

m. One pair of scissors and a knife.

n. One pair of safety goggles or face shield and respirator for each workman.

o. One 1 inch side putty knife (spatula) per workman.

p. Portable hand grinder with abrasive grinding disks. (Section VII, Article 30).

q. Soap and water available for immediate removal of epoxy materials from person.

r. Stop watch or other timer. (Section VI, Article 26)

s. Tarps for floor covering if required

t. Thermometer.

u. Quick set epoxy. (Section VIII, Article 35)

3. Preparation of the Cracks

a. If debris is present in the crack, blow out using an air jet. (Section V, Article 20 b)

b. Clean crack surfaces with solvent. (Section V, Article 20 a)

c. Glue fittings onto the cracks. (Section V, Article 21)

1. Spacing and location of fittings as specified by job superintendent.

2. Coat unreamed end of fitting with contact cement. Several can be coated at one time. Care must be taken not to clog the end. Allow contact cement several minutes to become tacky.

3. Press the coated end firmly against the concrete or masonry over the crack. If fitting does not stay in place, the cement has not dried sufficiently.

4. If the crack is in a corner, or the surface around the crack is irregular and rough; and it, therefore, becomes difficult to get the fitting to adhere to the concrete or masonry; grind or file the unreamed end to a shape which will allow more contact area for gluing.

d. Mix one pint of the crack sealing epoxy. (Section V, Article 21 d and Article 22)

e. Seal cracks and fittings. (Section V, Article 21 d)

1. Using putty knife (spatula) spread sealing epoxy along the cracks to a thickness of 1/16 to 1/8 inch and at a width of approximately 2 inches. Carefully seal around the fittings tapering the thickness up to approximately 1/2 inch.

f. Allow seal to cure overnight.

4. Prepare Equipment for Grouting

a. Hand Gun (Section III, Article 12, Figures 1 and 2)

1. Mix one pint of epoxy grout according to manufacturers instructions.

2. With nozzle attached, fill the cartridge.

3. Place plastic cap in end of cartridge.

4. Insert the cartridge into the steel retainer barrel.

5. With ram mechanism fully retracted, thread steel cover onto the handle.

6. Engage rachet mechanism.

7. Cut 1/4 inch from end of nozzle.

8. Hand gun is ready for use.

b. Pressure Pot (Section III, Article 13, Figures 3, 4, and 5)

1. Assemble pressure pot connecting all injection and pressure lines and bring air source to proper working pressure.

2. Mix specified amount of epoxy grout in a 1/2 gallon container according to manufacturer's instructions. (Section VI, Article 25 b.)

3. Place container of grout into the pressure pot.

4. Replace lid of the pressure pot making sure the feeder line is in the container and secure tightly.

5. Shut off all exit valves to the grouting lines.

6. Close pressure regulator on the pressure pot so that no air can enter the pot when the entry valve is opened. (This step is required at the beginning of each days operation.)

Open entry valve and slowly open the pressure regulator until the desired pressure is read on the gauge.

*WARNING: NEVER EXCEED SAFE WORKING PRESSURE OF THE POT.*

8. Pressure pot is now ready for use.

5. Grouting Procedures

a. Introduction

Procedures to be followed when pressure grouting are exactly the same regardless of the equipment being used. It is not feasible to cover all possible aspects of grouting procedures due to the enumerable circumstances which may be encountered. Articles 26 a and b of Section IV and Section VIII describe the procedures which should be followed. A thorough understanding of the text of these articles should provide sufficient knowledge of pressure grouting procedures in order that the inexperienced operator can perform normal operations. This knowledge coupled with field experience and good judgement will enable the operator to handle any special problems which may arise.

b. Hand Gun (Section VI, Article 26 b)

1. Grouting begins at an end portal or the bottom portal of a crack.

2. Insert the nozzle into the portal opening.

3. Inject epoxy until it flows out of the next portal. (For special

cases of portal spacing, such as the use of intermediate portals, see Section VI, Article 26)

4. Remove the hand gun and plug with a wooden dowel the portal just used.

5. Insert the nozzle of the hand gun into the next portal and inject epoxy.

6. Continue this procedure until the crack has been filled. When epoxy begins to flow out of the last portal, which is at the top or the end of a crack, the crack may be considered full. However, epoxy should be injected into this portal for a short time.

7. During the above process, the hand gun is refilled as required. (Section III, Article 12)

c. Pressure Pot (Section VI, Article 26 a)

1. Grouting begins at an end portal or the bottom portal of a crack.

2. Insert the epoxy injection line into the portal opening.

3. Open the exit valve and inject epoxy until it flows out the next portal. (For special cases of portal spacing, such as the use of intermediate portals, see Section VI, Article 26)

4. Close the exit valve, remove the injection line, and plug the portal with a wooden dowel.

5. Insert the pressure line into the next portal, open the exit valve, and inject epoxy.

6. Continue this procedure until the crack has been filled. When epoxy begins to flow out of the last portal, which is at the top or at the end of a crack, the crack may be considered full. However, epoxy should be injected into this portal for a short time.

7. During the above process, the pressure pot is refilled as required. (Section VI, Article 26 a and Section VIII, Article 34)

6. Clean-Up

a. General

1. All spillage of epoxy materials and solvents should be immediately wiped up with clean rags which are then put in disposable containers and removed from the job site.

2. All empty epoxy containers should be immediately placed in leak proof waste containers.

b. Pressure Pot (Section VII, Article 30)

1. Any delay in the pressure grouting operation (e.g. lunch break, quitting time, etc.) over fifteen (15) minutes in duration demands that the pressure pot be cleaned and all lines thoroughly cleared of epoxy compound as follows.

a. Open pot and remove epoxy containers

b. Insert a full container (1/2 gallon) of acetone or methyethyl ketone.

c. Close all exit valves in injection lines.

d. Remove the lines from the portals and place the ends in a waste container (such as an empty 5 gallon solvent can).

e. Pressurize the pot.

f. Open one exit valve at a time and flush until the line is cleared of epoxy.

g. When all lines are cleared, open all exit valves and flush simultaneously while intermittently opening and closing all valves through which the solvent is flowing.

h. When solvent in the tank has been depleted, replace it with a half full container of solvent and repeat the flushing process.

i. After the last container is empty, flush the entrie system with air.

j. Solvent should not be reused and must be properly disposed of.

k. The outside of the pot, valves, lines, and all fittings should be thoroughly wiped clean with a solvent soaked rag.

c. Hand Gun (Section VII, Article 30)

1. All metal components of the hand gun should be thoroughly cleaned with solvent each time a cartridge is removed.

2. All used cartridges should be discarded in a metal waste container and never with or near solvent or solvent soaked rags.

d. Job Site (Section VII, Article 31)

1. After a crack has been completely injected and the adhesive has cured, the following procedure is followed.

a. The injection fittings are removed by tapping with a hammer. (Goggles must be worn)

b. The epoxy seal is removed by grinding.

2. A general clean up of the area should follow.